# A Hadron Blind Detector Upgrade for the PHENIX Experiment

Zvi Citron for the PHENIX Collaboration
*Dept. of Physics and Astronomy, Stony Brook University*
*Stony Brook, NY, 11794-3800, USA*

**Abstract**

Color neutral probes provide an effective way of "seeing inside" the new state of matter created in RHIC collisions. To this end, one of the primary goals of the PHENIX experiment is the study of low mass electron-positron pairs. The chief obstacle to this measurement is the large combinatorial background produced by random combinations of electrons and positrons that were not created as pairs. The dominant sources of these are $\pi^0$ Dalitz decays and photon conversions. These electron-positron pairs have a small opening angle, which can be used to identify them; once identified they can be precluded from pairing with other electrons and positrons thereby greatly reducing the random combinatorial background. The PHENIX hadron blind detector (HBD) was built expressly for the purpose of identifying electrons from $\pi^0$ Dalitz decays and photon conversions by their small opening angle. Each half of the detector consists of ten triple-GEM stacks whose top most GEM is coated with CsI, making the device photosensitive in the deep ultraviolet. Cherenkov light from relativistic electrons forms unfocused blob patterns on the cathode, which are then analyzed to identify electrons. The HBD was installed in the 2007 RHIC run. Results from the 2007 run and subsequent developments are discussed.

*Key words:* Gas Electron Multiplier, Cherenkov, Hadron Blind, Di-electron
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## 1. Introduction

One of the primary goals of the PHENIX experiment is the study of low mass electron-positron pairs. The measurement of such pairs is made difficult by the large combinatorial background produced by random combinations of electrons and positrons that were not created as pairs, predominantly $\pi^0$ Dalitz decays and photon conversions. The difficulty of the measurement is exacerbated by the case in which only one half of a dielectron pair is detected due to the incomplete azimuthal acceptance of PHENIX and low momentum electrons spiraling in the magnetic field without reaching the detectors. The Hadron

Blind Detector (HBD) upgrade addresses these challenges by detecting electrons in the field free region immediately about the collision point, and identifying $\pi^0$ Dalitz decays and photon conversions by their small opening angle.

## 2. Detector Design

The HBD is a windowless Cherenkov light detector that uses $CF_4$ as both the radiator and detector gas. It is constructed of two semi-circular arms positioned on either side of the collision point, extending radially from 5 to 65 cm around the beam pipe (Fig. 1a). To detect the Cherenkov light radiated by an electron a triple stack of gas electron multipliers (GEMs) [1] is equipped with a $CsI$ photocathode evaporated onto the top GEM surface. Primary photons from the Cherenkov radiation of an electron create photo-electrons in the $CsI$ which are then avalanched by the GEM stack with an effective gain on the order of $10^4$. To achieve hadron blindness a mesh is placed 1.5 mm above each GEM stack to provide voltage bias with reverse polarity relative to the GEM operating voltage. This draws away from the GEMs hadron ionization while allowing Cherenkov photons to pass through to the photocathode (Fig. 1b). The avalanched signal is collected on 2.2 cm$^2$ hexagonal pads under the stack. Each GEM is 27x22 cm$^2$, and ten GEM triple stacks are installed in each arm of the HBD. The GEM stacks and meshes are powered independently by LeCroy 1471 modules.

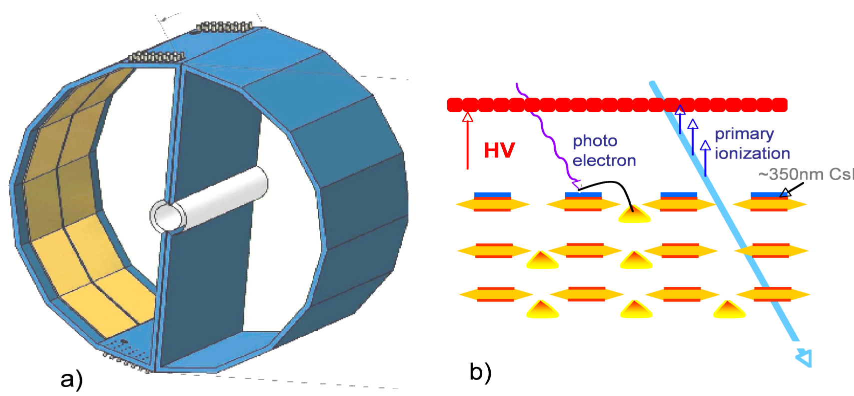


Fig. 1. a) A schematic view of the two arms of the HBD with the beam pipe shown in the center. The placement of the GEM triple stacks is visible on the left. b) An illustration of the triple GEM stack operation. A Cherenkov photon is depicted creating a photoelectron in the $CsI$ photocathode which is then avalanched through the GEM stack.

## 3. Operation in the 2007 RHIC Run

The HBD was installed in PHENIX for the 2007 RHIC run. There was difficulty maintaining voltage in the GEM stacks as micro-sparks in the GEMs led to power supply trips. These GEM power supply trips led to a large voltage difference between the top GEM and the mesh before the mesh power supply responded. This created a large spark between the mesh and top GEM, that was powerful enough to damage the GEM. The spark was sufficiently bright that its light output also tripped other stacks within its line of sight creating a chain reaction of trips. These problems did not allow sufficient active area for physics running, as well as forcing the post run dismantling of the detector to replace the damaged GEMs.

Despite this, valuable proof of principle results were obtained from the data taken with the HBD while functioning. By identifying electrons and hadrons in the outer PHENIX detectors and then analyzing the HBD's response to them we found that it did successfully function as a hadron blind electron detector. A clear separation in the detector's response to hadrons and electrons, respectively, is shown in Figure 2a. Figure 2b shows the di-electron yield as a function of invariant mass with and without utilizing the HBD in the analysis for peripheral events. This preliminary analysis shows a clear reduction in the combinatorial background. By using the HBD the signal to background ratio increases from 15 to 250 for m<0.15 GeV/$c^2$ and from 0.04 to 1.25 for m>0.15 GeV/$c^2$.

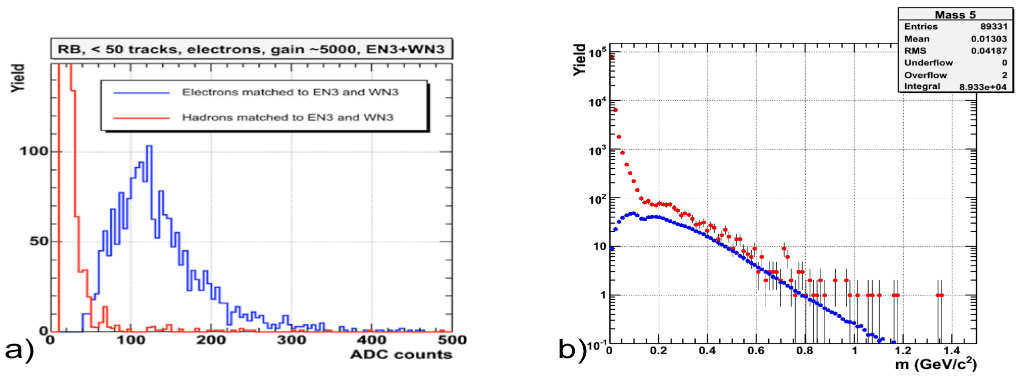


Fig. 2. a) In red is the HBD's low response to hadrons distinct from the electron signal in blue. b) Shown in red is the di-electron yield as a function of invariant mass without the HBD, and in blue the yield using the HBD's rejection capabilities.

## 4. Subsequent Developments

Both arms of the HBD were dismantled following the 2007 RHIC run and the detector was repopulated with new GEMs to replace the damaged ones. Safeguards were added to the power supply chain to prevent mesh to GEM sparks from occurring following a trip, and the trip procedure was updated to minimize trips. In addition the high voltage configuration was altered: to increase the gain without increasing the voltage across a GEM the voltage between GEMs was increased, and by lessening the voltage between the mesh and top GEM the light yield may be improved while maintaining hadron blindness. The refurbished detector has been reinstalled in PHENIX and successfully tested in preparation for the 2009 RHIC run.

## References


[1] F. Sauli ,NIM A 386 (1997) 531